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An Evaluation and Preliminary Update for the LBL Circumsolar Telescope

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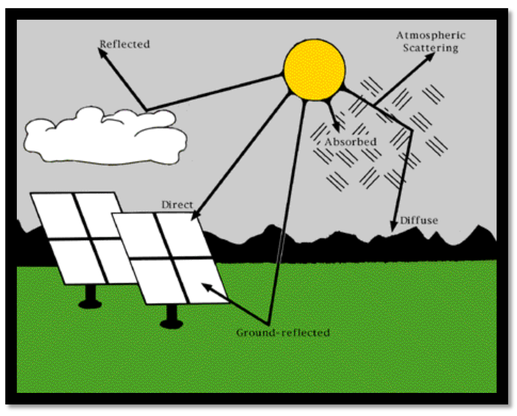
Purpose

The DOE and NREL's objectives include the continued development and implementation of renewable energy technologies. Key concerns regarding solar radiation collection devices are their efficiency and their viability as a technology depending on a location. The expected performance of ground-based focusing collectors is based on pyrheliometer data and calculations which assume the solar flux is concentrated within the 0.54 degrees or 32 arcminute angle subtended by the Sun. However, molecules, particulates and aerosols in the atmosphere scatter solar radiation, including in what is an additional circumsolar radiation region [2]. Solar collection devices cannot absorb circumsolar radiation.

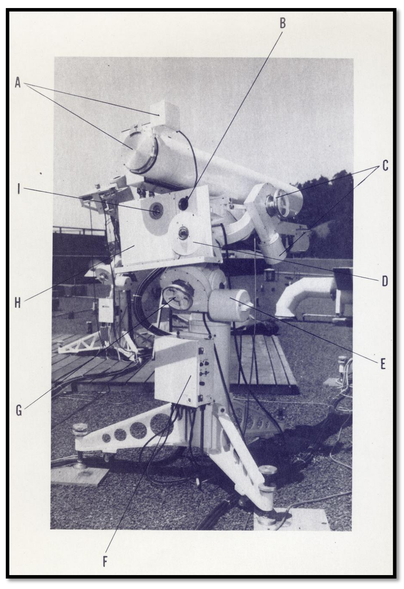


Solar radiation is scattered, absorbed, and reflected by the atmosphere and the Earth, limiting the direct radiation which reaches solar collectors [1]

Continued research regarding the circumsolar radiation region and thus the error in pyrheliometer data requires the resurrecting of the Circumsolar Telescope, built by the Lawrence Berkeley Laboratory's Energy in the late 1970's.

Instrument Design

The Circumsolar telescope was used to track the sun and measure the distribution of solar radiation. Tracking, control and data collection were done electronically and operation was almost entirely automatic aside from routine checks..

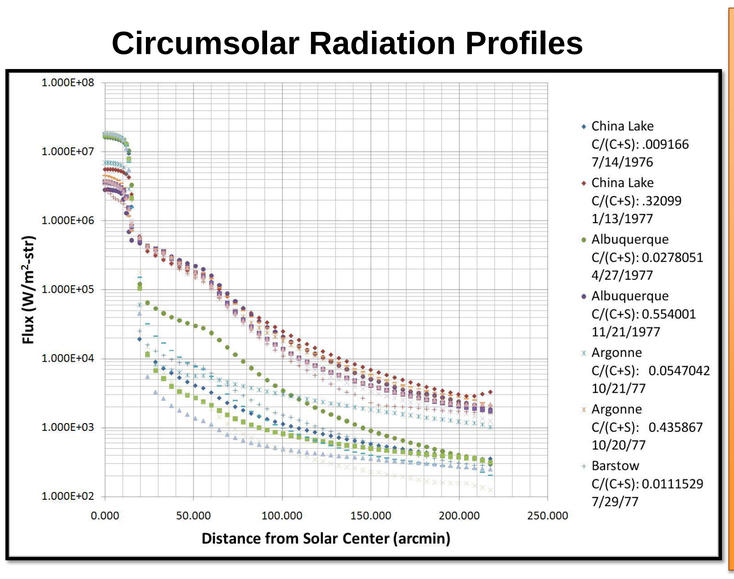


A. Rain Flapper and Box—sensor automatically closes if there is rain
B. Solar Guider—aligns instrument platform to center of Sun
C. Declination correction motor and manual handwheel
D. Tracking pyranometer—measures insolant radiation
E. Right ascension clock and correction motors
F. Solar tracker electronics and control box
G. Right ascension manual handwheel
H. Instrument platform
I. Pyrheliometer aperture—measures direct solar radiation within a five degree field of view

Methods

- Observe and analyze components; clean instruments
- Determine S/Ns, sensitivities, etc. of components in order to research specifications and determine potential upgrades.
- Test pyranometer responsivity by calibrating with baseline array
- Connect and test pyrheliometer to determine if it is working; calibrate if possible (requires removal from telescope system).
- Analyze LBL data from database for comparison
- Operate telescope manually to obtain data using Ocean Optics Spectrometer
- Obtain data from Kipp & Zonen POM-01 scans for comparison
- Compare results with turbidity and cloud cover data
- Determine best upgrade components

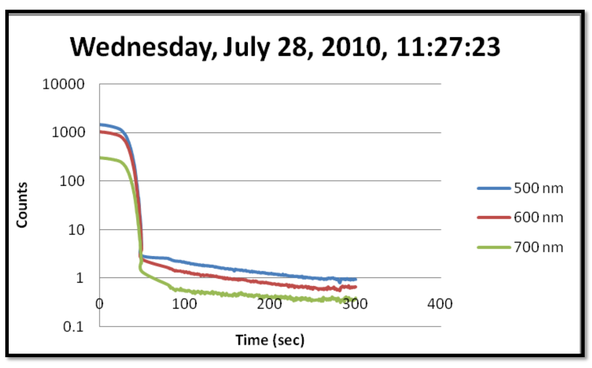
LBL Database

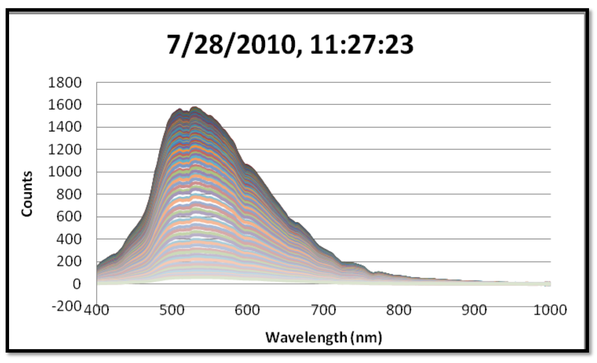


Data from Lawrence Berkeley National Laboratory Circumsolar radiation database. Each site contains two plots—one for a low circumsolar to solar radiation ratio (C/(C+S) <0.2), one for a higher C/(C+S) value. Selected data does not contain "flags" which indicate errors/problems (e.g. rain flap is down, aperture switch did not occur properly).

Preliminary Data

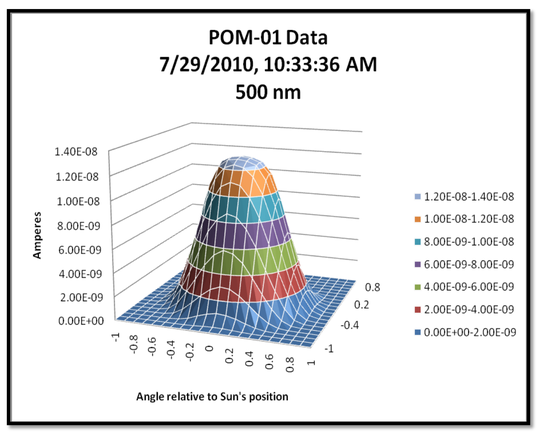
After cleaning and analyzing the components, an ocean optics spectrometer was used in lieu of the pyroelectric detector. The mirrors were adjusted for alignment, which is done using a target square and eyepiece, and sample data was taken.





Examples of data taken manually at 11:27 AM on July 28th over a range of 400 to 1000 nm using an Ocean Optics spectrometer. On the left are plots of 500, 600 and 700 nm profiles changing over time as the position relative to the Sun changes. The graph on the right shows spectral curves, with the top curve containing data from the center of the Sun, the bottom well within the Circumsolar region. Both graphs have a setting of "boxcar 20" which averages every 20 points as one to reduce the noise and error. Continued data reduction and analysis are still to come.

POM-01 Data



POM-01 data showing the amount of amperes relative to the instruments position from the center of the sun. Scans occurred over a period of 20 minutes, within a region of ± 1°.

Pyranometer Calibration

The Eppley pyranometer used for normal insolant radiation measurements was calibrated at SRRL. The equation for responsivity is

$R=(V-R_{net}*W_{net})/I$
Where R=responsivity ($\mu V/W/m^2$)
V=voltage in microvolts
R_{net}=radiometer net infrared responsivity
W_{net}=effective net infrared measured by pyrgeometer (W/m^2)
I=reference irradiance (W/m^2)

The responsivity labeled on the device by Eppley was 9.25 $\mu v/W/m^2$ whereas the calibration shows a result of 8.52 $\mu v/W/m^2$ at a zenith angle of 45°, meaning a decrease in responsivity of about 8% has occurred over approximately 30 years [3].

Analysis and Conclusion

- Pyranometer calibration reveals a degradation in responsivity of about 8%—requires servicing or replacement.
- Pyrheliometer could not be tested due to the fact it requires a chopper and electronics system is currently inoperable.
  - The potential for degradation as with the pyranometer is highly likely as well. Can replace with Kipp & Zonen CHP1 or similar Eppley model.
- Replacement of detector with either a spectrometer or spectrograph, or an all in one probe with chopper and detector both appear to be potential options. Data using both systems for comparison would be best although this may not be financially feasible. Potential systems come with their own software, which can be an advantage, but also a disadvantage if software rewrites are required depending on the ease of the process.
  - Incorporation of spectrometer yielded similar profiles although further analysis and comparison are still ongoing.
  - Need to better determine ideal integration times and when to shift integration times depending on solar region (disk vs. circumsolar).
- Tracker not tested due to uncertainty in condition of electronics; requires further study and analysis.

References

[1] B. Marion, C. Riordan & D. Rennè, "Shining On: A Primer on Solar Radiation Data," 1992, http://www.nrel.gov/docs/legosti/old/4856.pdf.
[2] D.F. Grether et. al., "Circumsolar Radiation Telescope," Sunworld, vol. 4, no.3, 96-98, 1980.
[3] Myers, D., Gotseff, P. RCC/BORCAL Calibration Certificate for Eppley Precision Spectral Pyranometer 13893F3, 27 July 2010.

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